NUMERICAL ANALYSIS OF BLAST PRESSURE PARAMETERS FOR THE PLANT AND WALL AS BARRIER

NUR SYAHIRAH BINTI BASRI SHAFF

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : Nur Syahirah binti Basri Shaff

ID Number : AA15156

Date : 17 June 2019

NUMERICAL ANALYSIS OF BLAST PRESSURE PARAMETERS FOR THE PLANT AND WALL AS BARRIER

NUR SYAHIRAH BINTI BASRI SHAFF

Thesis submitted in fulfillment of the requirements
for the award of the
B.Eng (Hons.) Civil Engineering

Faculty of Civil Engineering and Earth Resources

UNIVERSITI MALAYSIA PAHANG

JUNE 2019

ACKNOWLEDGEMENTS

Bismillahirrahmanirrahim,

I am sincerely grateful to ALLAH “S.W.T” for giving me wisdom, strength, patience and assistance throughout this project until the project is successfully completed. With the mercy of Allah therefore I gained a lot of fruitful ideas to complete this project.

This project would not have been possible without the help and guidance of several individuals who contributed and extended their valuable assistance upon the completion of this project. I am deeply indebted to my supervisor, Dr. Mazlan bin Abu Seman for his patience, guidance, insightful comments, advice and encouragement which helped me to accomplish my final year project.

I also would like to convey many thanks to the faculty (FKASA) for providing the laboratory facilities and workshop to conduct this project. My sincere appreciation also extended to all my teammates, lecturers, technicians and others who provided assistances and advices, including the crucial input for my planning and finding. The guidance and support received from all were vital for the success of this research.

Other special thanks would also be addressed limitlessly to my family for their unconditional love and support financially and emotionally until the project is completed. Finally, I would like to thank everyone who had involved in completing this project directly or indirectly. I am beyond grateful for all that presents.

ABSTRAK

Tumbuhan ditanam secara meluas di banyak kawasan bertujuan untuk menghalang hakisan tanah apabila berlakunya hujan lebat dan ribut. Pada masa kini, penanaman pokok lebih cenderung untuk ditanam untuk tujuan estetik di mana tumbuhan dipotong kepada bentuk untuk mencantikkan tempat. Terdapat kajian yang menyiasat tumbuhan sebagai penghalang apabila dikenakan beban ledakan. Walau bagaimanapun, hanya terdapat beberapa jenis penyelidikan mengenai tumbuhan yang diterbitkan secara akademik mengenai tumbuhan sebagai penghalang. Oleh itu, bacaan akademik secara umum mengenai tumbuhan sebagai penghalang pada dasarnya adalah terhad. Percubaan yang diterbitkan dan boleh diakses untuk rujukan kajian ini ialah kerja menumpukan pada objek yang berbeza yang bereksperimen untuk keupayaannya untuk menyerap atau mengurangkan tekanan letupan. Ia bertujuan untuk mengkaji parameter tekanan letupan sebanyak 30 lbs. (13.61 kg) Trinitrotoluene (TNT). Oleh itu, siasatan lanjut dijalankan untuk dinding RC dan tumbuhan tertakluk kepada beban letupan terutama pada pergantungan mesh tepat terhadap AUTODYN. Experiment ini bertujuan untuk mengkaji parameter tekanan letupan sebanyak 30 lbs. (13.61 kg) Trinitrotoluene (TNT). Analisis elemen terhingga AUTODYN yang tidak linear (FE) adalah perisian komersil yang digunakan untuk membangunkan angka yang disahkan mengikut data tekanan letupan yang direkodkan dari percubaan sebelumnya. Simulasi berangka untuk analisis tekanan letupan dijalankan pada empat kes halangan objek yang berbeza. Kajian numerik kini melibatkan kes-kes di ruang terbuka tanpa sebarang benda yang bertindak sebagai penghalang, RC yang bertindak sebagai penghalang, tumbuhan jenis umum yang bertindak sebagai penghalang dan kedua-dua pokok serta dinding RC bertindak sebagai penghalang. Keempat-empat kes ini dimodelkan dalam ANSYS-workbench dan disimulasikan dalam AUTODYN. Keputusan berangka yang diperolehi diikuti oleh keputusan yang disahkan yang dilaporkan oleh penyelidikan terdahulu untuk pengesahan. Kajian ini membuktikan kes numerik dengan satu-satunya tumbuhan sebagai penghalang menunjukkan pengurangan tekanan ledakan tertinggi sebanyak 9.8% dan 6.7% berbanding dengan kes dengan dinding RC dan kedua-dua tembok dan loji RC. Ini mungkin disebabkan oleh tumbuhan yang menyerap tekanan letupan menyebabkan tekanan letupan berkurangan kepada 290 kPa manakala Case 2 dan Case 4 dikurangkan kepada hanya 490 kPa dan 310 kPa. Keputusan terhadap dinding RC diperolehi menunjukkan pengurangan tekanan terendah apabila tekanan menghasilakn permukaan dinding apabila gelombang itu melanda. Refleksi gelombang letupan telah menyebabkan tekanan ledakan meningkat. Siasatan lanjut disyorkan terutamanya pada ketepatan meshing untuk kedua-dua dinding RC dan tumbuhan sebagai penghalang apabila dikenakan beban ledakan.

ABSTRACT

Plant is widely planted in many areas mainly to prevent soil erosion and as shading purpose from storm and heavy rain. Nowadays, planting plant is more likely to plant for aesthetical purpose in which the plant is cut to shapes to beautify a place. Previously, there was a research carried out that investigated plant as barrier when subjected to blast load. However, there are only few researches on plant academically published regarding plant as barrier. Thus, the academic reading on plant as barrier is basically limited. The published experiment and accessible for reference of this present study is the work focusses on different objects that is experimented for its ability to absorb or reduce blast pressure. It aims to study the blast pressure parameters of 30 lbs. (13.61 kg) Trinitrotoluene (TNT). Thus, further investigation is required for both RC wall and plant subjected to blast load especially on the appropriate and accurate meshing dependency in AUTODYN. Present work aims to study the blast pressure parameter of 30 lbs. (13.61 kg) Trinitrotoluene (TNT). The AUTODYN non-linear finite element (FE) analysis is commercial software used to develop a validated numerical according to the recorded blast pressure data from previous experiment. Numerical simulation for blast pressure analysis is conducted on four cases of different object barrier. The present numerical study involved cases at open space without any objects acting as barrier, only RC wall acting as barrier, only plant of general type acting as barrier and both plant and RC wall acting as barrier. These four cases are modeled in ANSYS-workbench and simulated in AUTODYN. The numerical results obtained are followed by a validated results reported by previous researches for validation. The present study established that, numerical case with only plant as barrier showed the highest blast pressure reduction by 9.8% and 6.7% compared to cases with RC wall and both RC wall and plant respectively. This might due to the plant that absorbs the blast pressure causing the blast pressure to be significantly reduced to 290 kPa whilst Case 2 and Case 4 reduced to only 490 kPa and 310 kPa respectively. Cases with RC wall present showed the lowest pressure reduction as the pressure reflects the wall surface when the wave hits. The reflection of the blast wave had caused the blast pressure to be magnified. Further investigation is recommended especially on meshing precision for both RC wall and plant as barrier when subjected to blast load.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

$Y_c(p^*)$	Compressive meridian
$F_{elastic}$	Ratio of the elastic strength to failure surface strength
$F_{cap\ (p)}$	Function that limits the elastic deviatoric stresses
B	The residual failure surface constant
M	Residual failure surface exponent
$D1$ and $D2$	Material constants for effective strain to fracture
$G_{fracture}$	Shear modulus
$G_{elastic}$	Shear modulus
$G_{residual}$	Shear modulus
E_p	Effective plastic strain
T_{room}	Room temperature
T_{melt}	Melting temperature
γ	Ratio of specific heat
ρ	Air density
E_i	Specific internal energy
P	etonation point pressure
D	Damaged scalar

LIST OF ABBREVIATIONS

ALE	Arbitrary Lagrangian Eulerian
FE	Finite Element
Ft.	Feet
JWL	Jones-Wilkins-Lee
JC	Johnson and Cook
Kg	Kilogram
lbs.	Pound weight
m	Meter
mm	Milimeter
msec	Milisecond
MPa	Mega pascal
Psi	Pound per Square Inch
RC	Reinforced Concrete
TNT	Trinitrotoluene

CHAPTER 1

INTRODUCTION

1.1 Research Background

Today's terrorist activities and threats have become massive and on-going problems all over the world. Countries especially in the middle-east are continuously being bombed. These countries that are continuously threated by wars have gone through a huge losses and damages in terms of property and also the people (Remennikov et al, 2005). However, an explosion or a blast load is not only related to bomb. It can also be battery explosion, gas leakage and industrial plants related. Blast load is an overpressure explosive material that results in a large dynamic load that will then cause injuries to the people and catastrophic damages to the buildings both internally and externally. The results may cause the collapsing of buildings, blowing out of windows and debris and breaking down of building safety system due to the dynamic load created by the explosion is higher than the original design loads for which the structures are analysed and designed.

The study of structure to find a blast resistance material has become a significant study due to the blast load case that occurred on December 11, 2005 at the Buncefield Oil Storage Depot. The explosion had caused so much loss such as homes and businesses surrounding the area (Scott G.Davis, 2010). Due to space constraint, development had to be done next to the dynamic loading prone area mentioned earlier. In order to cater this dynamic loading phenomenon towards the safety of the civilians, one of the effective approaches is by investigating the efficiency of tree to reduce or absorb blast wave to prevent the blast wave from harming the civilians and damaging the buildings.

In this study, a presentation of a three-dimensional (3D) model with a specified tree positioned at certain standoff distance from the explosive material is to be designed. This design is modelled to analyse the efficiency of a specified tree to absorb blast wave to reduce the negative impact surrounding the explosion area. Apart from that, a reinforced concrete (RC) wall of several proposed dimensions is also included as model to investigate the blast overpressure parameter at 30 lbs. TNT of blast with the presence and the absence of the RC wall. The RC wall and the specified tree will also be arranged differently to compare the amount of pressure exerted on each of the arrangement to be simulated in the selected software. This 3D modelling will be constructed and designed by using nonlinear finite element analysis software which is AUTODYN. AUTODYN is an integrated explicit tool to model a nonlinear dynamics of solid, fluid and gas that uses finite elements (FE), finite volume (CFD) and mesh-free particle (SPH).

1.2 Problem Statement

There are many life risking explosions that had occurred in our world nowadays. These explosions of different weight and strength had brought a great impact on people and environment. It has caused the death of people living nearby the explosive material such as the explosion of the oil storage terminals, nuclear plant, and rocket fuel containing flammable gas (Zipf et al. 2010). In this case, there have been a lot of towns and residential areas built near to those explosive material plants due to space constraints. The occurrence of an explosion is an instant reaction with dynamic pressure acting on it. The blast waves will propagate around the area and blow away the residential areas, buildings and towns. These damages will cause the repairing and maintaining cost to be higher due to severe damages caused by the explosion (Luccioni et al., 2004).

Other than that, explosion will also bring damages to human health. The blast wave produced by the explosion will cause ruptures to people’s eardrums in about 1% for every 5 psi of blast overpressure and also brings damages to the lungs at about 15 psi of blast overpressure. 1% fatality might occur if 35-45 psi of blast overpressure is subjected to blast load (Glasstone S, 1977). However, most common injuries are due to the flying debris and collapsing structures that strike civilians. Long-term effect of an explosion may cause eye-cataracts to human according to a study of Chernobyl Clean-up workers. These are the dangerous and harmful risks.

Therefore, it has been a significant effort in finding the solution towards saving life and protecting the environment. This research is carried out specifically to investigate plant as blast wave absorbent to reduce the propagation of waves travelling farther and affects the environment and civilians apart from analysing the physical impact of plant with the presence and the absence of RC wall.

1.3 Research Objectives

The objectives of this research are as follow:

- To investigate the blast pressure parameter of 30 lbs. TNT.
- To study either plant is able to reduce or absorb blast pressure.

1.4 Scope of Research

This study is focused on developing a three-dimensional (3D) model to analyse a fully integrated engineering analysis codes specifically designed for non-linear dynamic problems. This 3D model is developed in order to acknowledge the efficiency of plant to absorb shock wave produced by an explosion and able to safe life and buildings. Besides, this 3D model is also done to observe the blast pressure parameter of 30 lbs. Trinitrotoluene (TNT). The Arbitrary Lagrange Euler (ALE) processer is performed in the AUTODYN software to simulate the blast pressure analysis. The blast load is subjected to 30 lbs. TNT that comes from the explosion of various explosive sources. The validation of the blast pressure will also be done by comparing the research work reported by Yan et al. (2011). The result obtained from the simulation will specify the amount of pressure exerted at the back of the plant at 4876.8 mm (16 ft.). Distance from one pressure transducer to another is 1219.2 mm (4ft.).

The surrounding of the explosion area is modelled with a structural wall sizing 1829 mm x 1219.2 mm. The thickness of the wall is 152 mm with 305 mm of strip

REFERENCES

Abd-alrazaq, A. H. (2018) 'BENDING AND SHEAR RESPONSE OF CONCRETE BEAM', (January).

Gebbeken, N., Warnstedt, P. and Rüdiger, L. (2017) 'Blast protection in urban areas using protective plants', (December). doi: 10.1177/2041419617746007.

Gharehdash, M. Barzegar, I. Palimskiy (2019) 'PT US CR', *International Journal of Impact Engineering*. Elsevier Ltd. doi: 10.1016/j.ijimpeng.2019.02.001.

Keller, J. O,M. Gresho, A Harris (2014) 'What is an explosion?', *International Journal of Hydrogen Energy*. Elsevier, 39(35), pp. 20426–20433. doi: 10.1016/j.ijhydene.2014.04.199.

Lecture, N. (1977) 'Numerical methods: simulations with smoothed particle hydrodynamics 2'.

Luccioni, B. M., Ambrosini, R. D. and Danesi, R. F. (2004) 'Analysis of building collapse under blast loads', *Engineering Structures*, 26(1), pp. 63–71. doi: 10.1016/j.engstruct.2003.08.011.

Martin, R. J., Reza, A. and Anderson, L. W. (2000) 'What is an explosion? A case history of an investigation for the insurance industry', *Journal of Loss Prevention in the Process Industries*, 13(6), pp. 491–497. doi: 10.1016/S0950-4230(99)00082-0.

Ngo, T. Mendis, Gupta, Ramsay (2007) '-Blast Loading_Mendis.Pdf', *Electronic Journal of Structural Engineering*, (Special Issue: Loading on Structures (2007)). doi: 10.4028/www.scientific.net/AMM.94-96.77.

Nyström, U. and Gylltoft, K. (2009) 'Numerical studies of the combined effects of blast and fragment loading', *International Journal of Impact Engineering*, 36(8), pp. 995–1005. doi: 10.1016/j.ijimpeng.2009.02.008.

Panowicz, R., Konarzewski, M. and Trypolin, M. (2017) 'Analysis of criteria for determining a TNT equivalent', *Strojniski Vestnik/Journal of Mechanical Engineering*, 63(11), pp. 666–672. doi: 10.5545/sv-jme.2016.4230.

Rasbash, D. J. (2003) 'Explosion hazards and evaluation', *Fire Safety Journal*, pp. 203–204. doi: 10.1016/0379-7112(84)90044-4.

Remennikov, A. (2007) 'The state of the art of explosive loads characterisation', pp. 1–25.

Remennikov, A. M. and Rose, T. A. (2005) 'Modelling blast loads on buildings in complex city geometries', *Computers and Structures*, 83(27), pp. 2197–2205. doi:

10.1016/j.compstruc.2005.04.003.

Robertson, N., Hayhurst, C. and Fairlie, G. (1994) ‘Numerical simulation of impact and fast transient phenomena using AUTODYN^{TM}-2D and 3D’, *Nuclear Engineering and Design*, 150(2–3), pp. 235–241. doi: 10.1016/0029-5493(94)90140-6.

Taniguchi, M.Yoshida, Mario, Oshima, Hiromitsu (2004) ‘Effects of explosion energy and depth to the formation of blast wave and crater: Field Explosion Experiment for the understanding of volcanic explosion’, *Geophysical Research Letters*, 28(22), pp. 4287–4290. doi: 10.1029/2001gl013213.

Trulsen, J. (1984) ‘A Comparative Study of ANSYS AUTODYN and RSPH Simulations of Blast Waves’, pp. 1–6.

Tu, Z. and Lu, Y. (2010) ‘Modifications of RHT material model for improved numerical simulation of dynamic response of concrete’, *International Journal of Impact Engineering*. Elsevier Ltd, 37(10), pp. 1072–1082. doi: 10.1016/j.ijimpeng.2010.04.004.

Wang, Dan, Qian, Xinming (2017) ‘Numerical simulation analysis of explosion process and destructive effect by gas explosion accident in buildings’, *Journal of Loss Prevention in the Process Industries*. Elsevier Ltd, 49, pp. 215–227. doi: 10.1016/j.jlp.2017.07.002.

Yan, D. *et al.* (2016) ‘Blast response of full-size concrete walls with chemically reactive enamel (CRE)-coated steel reinforcement活性瓷釉涂层钢筋混凝土防护墙抗爆性能研究’, *Journal of Zhejiang University-SCIENCE A*, 17(9), pp. 689–701. doi: 10.1631/jzus.a1600480.

Zipf, R. K., Kenneth, P. E. and Cashdollar, L. (2010) ‘Explosions and Refuge Chambers: Effects of blast pressure on structures and the human body’. Available at: https://www.cdc.gov/niosh/docket/archive/pdfs/NIOSH-125/125-ExplosionsandRefugeChambers.pdf.